—研 究 論 文—
Scientific Paper

Underwater Observations of Ice Algae in Lützow-Holm Bay, Antarctica

Hiroshi SASAKI* and Kentaro WATANABE**

南極リュツォ・ホルム湾における Ice Algae の氷下観察

佐々木　洋*・渡辺研太郎**

要旨: 1983 年 1 月，南極リュツォ・ホルム湾定着氷域において，スキューバ潜水法を用いて，定着氷下の ice algae の直接観察を行った．その結果，海氷下面において，著しい水平的な不均一分布が認められた．また，海氷下面に付着する ice algae は容易に脱落すること，場所によっては海氷底部自体も壊れやすいなどの事実から，ice corer を用いて採取された氷柱サンプルによる現存量の測定には，定量的な問題が含まれることが示唆された．

Abstract: Heterogeneity in the horizontal distribution of standing stock of ice algae was observed by the SCUBA divings in January 1983, in a fast ice area of Lützow-Holm Bay, Antarctica. Colonies of ice algae easily came off from the undersurface of sea ice due to the mechanical disturbances from the ice corer and from water movements caused by a diver. The bottom layer of sea ice was here and there fragile as the substratum of ice algae and was susceptible to disturbances.

Based on the observations, the accuracy in the estimation of standing stock of ice algae was discussed.

1. Introduction

The current understanding of marine primary production in polar seas is that there is an additional production site in and under the sea ice (Fig. 1), other than the benthic and pelagic sites. Although ice algae are thought to have an important role in ice sea ecosystems (MEGURO, 1962; BUNT and WOOD, 1963; HOSHIAI, 1969), many investigators have encountered some difficulties of sampling operations in trying to make a quantitative study of ice communities (*e.g.* HORNER, 1977).

Some physico-chemical information on the ice habitat and on the proliferation of ice algae showed that solar radiation penetrating through the ice was the major factor controlling ice algae production, and therefore meteorological conditions such as weather, ice thickness and snow cover greatly affected the growth of the ice algae (BUNT and LEE, 1970; HORNER and SCHRADER, 1982). These observations also included suggestions on marked heterogeneity in distribution of ice algae.

* 東北大学農学部. Faculty of Agriculture, Tohoku University, 1–1, Tsutsumi-dori, Amamiya-machi, Sendai 980.

** 国立極地研究所. National Institute of Polar Research, 9–10, Kaga 1-chome, Itabashi-ku, Tokyo 173.

Fig. 1. Dense ice algal communities adhering to an ice block which was broken and turned up by the icebreaker FUJI.

To collect ice samples, previous workers usually used an ice corer and obtained a core sample from the top of the ice cover. However, when the ice corer was retrieved, the bottom part of the ice core was easily dissociated from the upper core, because the bottom algal layer was soft and the ice substratum was breakable (HORNER, 1977). Recent works on ice algae have been carried out using the SCUBA diving technique for the algae sampling as well as for the field experimentation to determine their productivity (CLASBY *et al.*, 1973).

This study aimed to examine some characteristics of ice algae distribution from direct observations using the SCUBA diving technique and to identify the problems described above.

Observations were done in January 1983 at a station (68°43′S, 38°46′E) situated about 40 km north of Syowa Station in Lützow-Holm Bay, Antarctica. The Japanese icebreaker FUJI stayed there for the summer operation of the 24th Japanese Antarctic Research Expedition (JARE-24), 1982–1983.

2. Methods

SCUBA divings and water samplings below the fast ice were performed from a hole of 1×2 m dug in the ice *ca.* 140 cm thick. The bottom depth of the sampling site was 280 m.

For the measurement of standing stock of phytoplankton in the water column, samplings were carried out at six layers at 0 (just beneath the sea ice), 1, 5, 10, 20 and 30 m depths using Van Dorn water bottles through the hole. One liter of water from each sample was filtered through a Whatman GF/C glass fiber filter for plant pigment determinations. The pigment measurement was done by a fluorometric method (STRICKLAND and PARSONS, 1972). Ice core samples were taken in triplicate with an

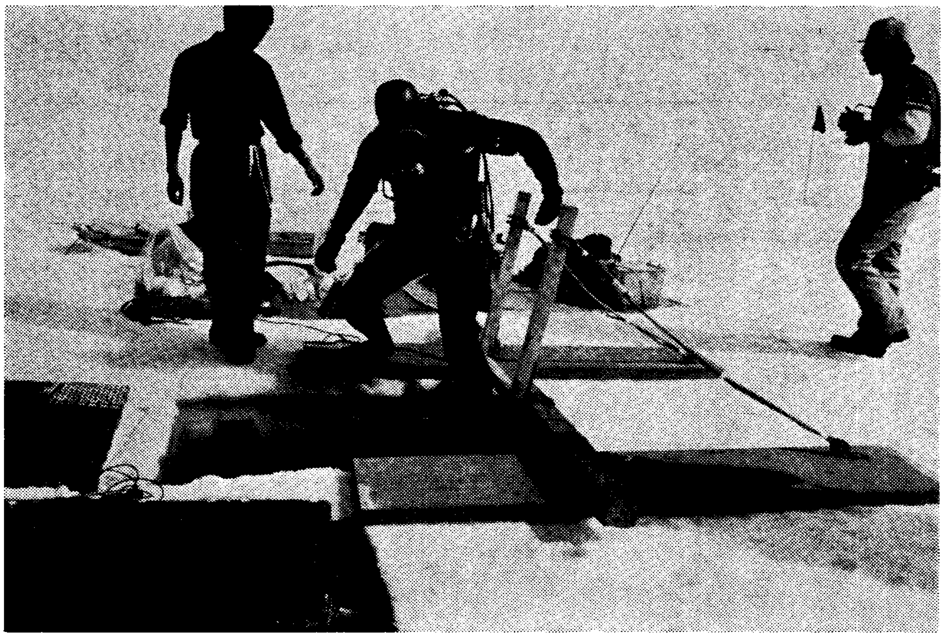

Fig. 2. An access hole in the fast ice and a diver equipped with SCUBA, single safety line, dry type suit, Wet Phone (an underwater ultrasonic communication system) and Wet Beacon (an underwater ultrasonic guiding system).

ice corer (SIPRE ice-coring auger, 8 cm in inner diameter) at the site close to the hole. The bottom 10 cm of core was used for the determination of plant pigments contained in the sea ice after melting the core in a laboratory on board. A SCUBA diving technique (Fig. 2) was similar to that reported by WATANABE *et al.* (1982). Visual observations were done with the aid of photographic records of ice algal community. Several algal flakes sinking from the undersurface of the ice were trapped into a 250 m*l* polyethylene bottle that was gently kept below the ice by the diver. Duplicate samplings were made and the bottles containing flakes were brought back to the laboratory and the water inside was analyzed for pigment contents. The amount of ice algae released from the ice was compared with the standing stocks in the ice core taken by a corer and the water sampled by water bottles.

3. Results and Discussions

In the upper 30 m water column, chlorophyll *a* concentrations were less than 0.1 mg/m^3 just below the ice and increased with depth having the maximum value of 0.35 mg/m^3 at 30 m depth (Fig. 3). There was not any remarkable diel change between the two observations at 0800 and 1800. SCUBA divings were made in the upper 10 m water column, where the phytoplankton biomass was fairly low and the water was rather clear. The distance that two divers could recognize each other was more than 10 m just below the fast ice.

The heterogeneous or patchy distribution of ice community on the undersurface of the fast ice was evidently observed by the underwater survey (Figs. 4, 5, 6 and 7). Standing stock data from the core samples of ice algae in the bottom part of the ice also revealed heterogeneity in horizontal distribution ranging from 0.75 to 3.45 mg/m^3

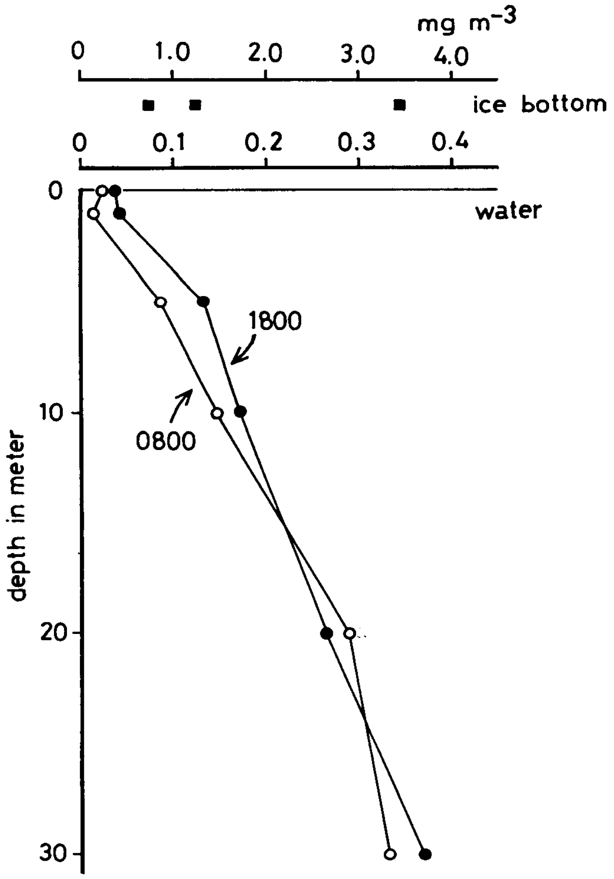

Fig. 3. Vertical distributions of chlorophyll a in the upper water column observed at 0800 and 1800, on 5 January 1983, and standing stocks of ice algae in the bottom 10 cm ice core.

within a small area of a few square meters, although only three data were available. Even in the relatively flat undersurface of the ice (Figs. 4 and 5), ice algae varied in distribution, probably due to the difference of light reaching the bottom of the ice. Ice algae adhering to the undersurface appeared to be fragile and had a sheet-like filamentous structure. The ice algal community was rarely found on the bottom of a small iceberg surrounded by the flat fast ice (Fig. 6). This iceberg was apparently thicker than the fast ice. The low light intensity probably limited the growth of the algal cells underneath.

Other than the hard ice crystals shown above, relatively soft and fragile ice could be often seen in the bottom part of the ice (Fig. 8). This sherbet-like ice with loose structure was found to contain the greenish brown layer colored possibly by algal cells. No dense algal community adhered to the undersurface of the sherbet ice.

According to the irregularity in horizontal distribution, it may be necessary to collect multiple samples at a station using an ice corer to estimate the average standing stock quantitatively.

We recognized the other difficulty in measuring the biomass of ice algae by the ice corer. Small holes of 13 cm in diameter were dug by a corer (Figs. 7 and 8). In Fig. 7, it was clearly found that ice algae around the hole had fallen away from the bottom ice possibly due to the mechanical disturbance by the corer. On the other hand, the lower soft ice would be dissociated from the upper part of the core sample when the corer was retrieved, and the missing of surrounding ice algae from the sherbet ice was not markedly seen (Fig. 8). It seems that an unknown amount of ice algae would be lost during the sampling process by the use of the corer. This undoubtedly caused an underestimate of standing stock of ice algae.

Epontic communities of the undersurface of the ice were easily disturbed by bubbles from the diver's breathing apparatus. Weak currents caused by a waving hand of the diver gave rise to the release of algae from the ice and they began to sink down to depths (Fig. 9). Most of sinking flakes of algal cells were long and slender having the size of a few centimeters long. Some of them were trapped in sample bottles by a diver. The amounts of chlorophyll *a* in the 250 m*l* sample bottles were as high as 0.033 and 0.026 mg, averaging 0.0295 mg included in several algal flakes. These values were comparable to the phytoplankton standing stock in 1 m^3 of the water just below the ice (Fig. 3).

On the vertical distributions of phytoplankton in the upper 30 m water column, the lowest biomass was found just below the ice and the concentrations increased with depth (Fig. 3). Judging from the profiles, the natural rate of the release of ice algae from the undersurface to the water column was not so high as to effectively influence the pigment concentrations of the water. If, however, the water samplings were performed after the ice core samplings and the SCUBA divings, the vertical distribution of chlorophyll *a* might be drastically changed because in this case a Van Dorn bottle would catch sinking ice algal flakes that freshly came off the ice.

The amount of 0.0295 mg passing through a mouth area of the 250 m*l* bottle (3 cm in diameter) is equal to the amount of 32.776 mg/m^2. This is about one order of magnitude higher than the chlorophyll content in 1 m^3 of ice as obtained by ice core samples. This rough calculation indicates that the missing of epontic communities from the undersurface of the fast ice would contribute to a serious underestimate of the standing stock of ice algae.

There might be two possibilities to account for this big discrepancy. The electromotive ice corer used during this operation made mechanical disturbances to the epontic algae much more severe than a hand-operated corer, and further, the algal communities at the ice bottom were apt to fall down quite easily in this period of the year (austral summer). Though accurate consideration cannot be made because of the insufficient experiments, the missing of ice algae might, more or less, occur whenever an ice core sampling is performed.

It appears very difficult to estimate the standing stock of ice algae quantitatively because of their heterogeneity in horizontal distribution and their easy release from the ice core samples. The direct observation and collection by a diver may be most effective for this purpose. We tried to advance a small ice core sampler (7 cm in diameter and 20 cm long) for the present study. It was used for a diver to cut into the bottom layer of the ice by rotating its serrate end. However, it was not easy for a diver to handle the sampler in an unstable situation, and no ice core sample could be obtained without making any disturbances to the epontic ice algae. More effective and easier method should be developed in future.

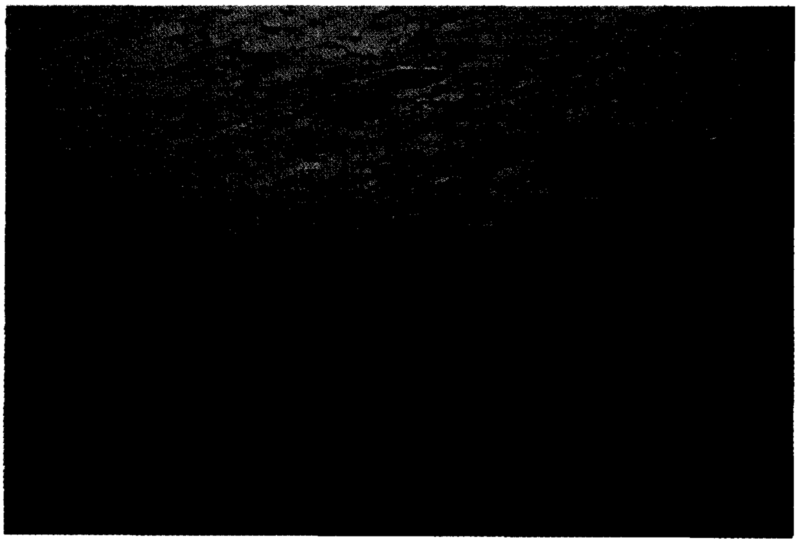

Fig. 4. Brown-colored ice algal communities adhering to the undersurface of the fast ice.

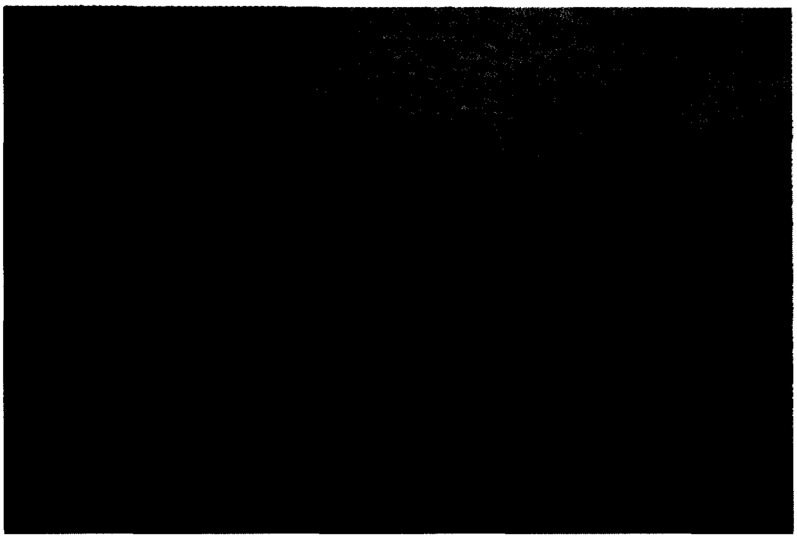

Fig. 5. Brown-colored ice algal communities adhering to the undersurface of the fast ice.

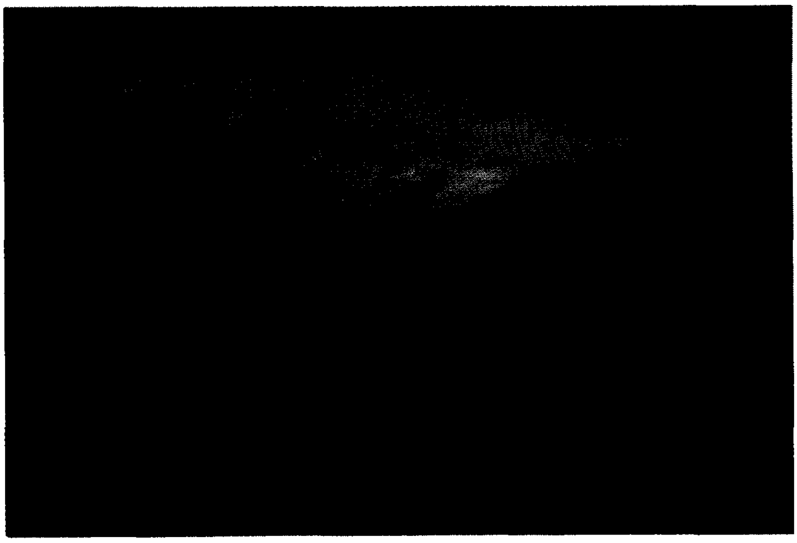

Fig. 6. A small iceberg enclosed by the fast ice and distinctive inhabitation of ice algae on the thick ice.

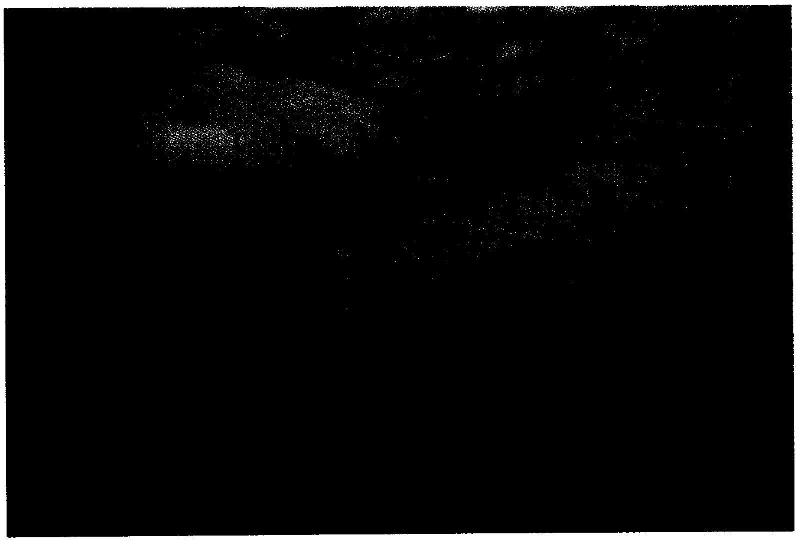

Fig. 7. A trace of missing ice algae from the undersurface surrounding the hole. Single line lowered through a small hole with a lead at the end.

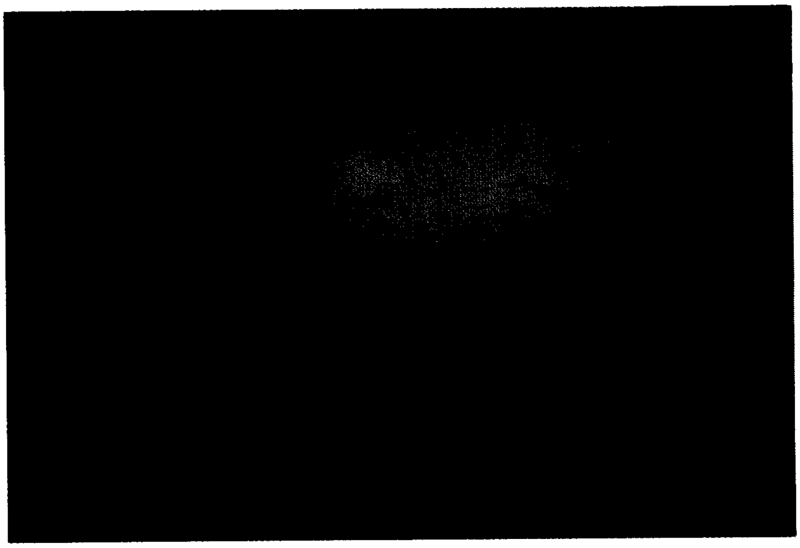

Fig. 8. A small hole dug through the soft and sherbet-like bottom ice in which the algal layer was contained.

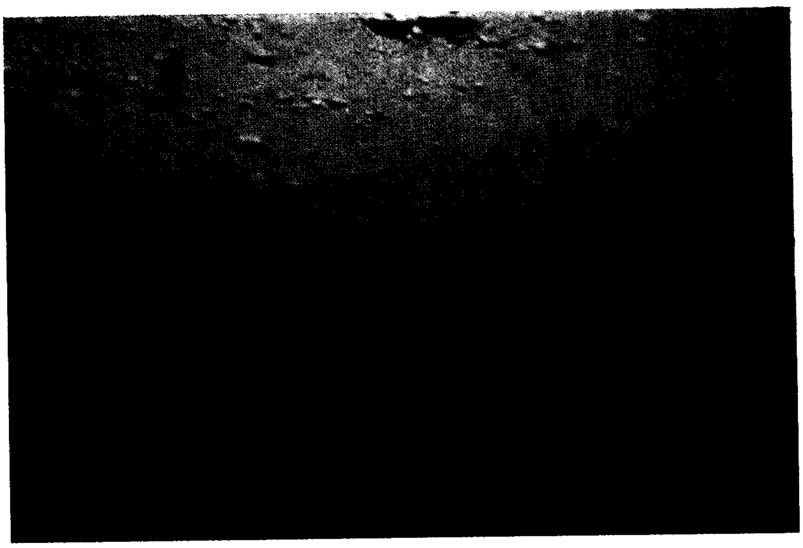

Fig. 9. Sinking flakes of epontic algae leaving from the undersurface of the ice by the disturbance of the diver's wake.

Acknowledgments

The authors wish to express their appreciation to Dr. S. MAE, the leader of the JARE-24, Dr. Y. OHYAMA, the deputy leader of JARE-24 and Mr. S. TAKEUCHI, the captain of the icebreaker FUJI. Thanks are also due to Dr. E. TAKAHASHI, Dr. H. KANDA, Dr. H. SATO, Mr. T. HANZAWA and Mr. K. IWAMOTO of the JARE-24 for their helpful cooperation. They wish to thank Dr. S. NISHIZAWA, Tohoku University, for correcting the manuscript.

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(Received November 30, 1983; Revised manuscript received January 9, 1984)